

## Description

# WAFER HOLDER FOR SEMICONDUCTOR MANUFACTURING DEVICE AND SEMICONDUCTOR MANUFACTURING DEVICE IN WHICH IT IS INSTALLED

### BACKGROUND OF INVENTION

[0001] Field of the Invention

[0002] The present invention relates to wafer holders employed in semiconductor manufacturing device such as plasma-assisted CVD, low-pressure CVD, metal CVD, dielectric-film CVD, ion-implantation, etching, Low-K film heat treatment, and degassing heat treatment device, and furthermore to process chambers and semiconductor manufacturing device in which the wafer holders are installed.

[0003] Description of the Background Art

[0004] Conventionally, in semiconductor manufacturing procedures various processes such as film deposition processes and etching processes are carried out on semiconductor

substrates that are the processed objects. Ceramic susceptors that retain such semiconductor substrates in order to heat them are used in the processing equipment in which the processes on the semiconductor substrates are carried out.

[0005] Japanese Pat. App. Pub. No. 2002-237375 for example discloses conventional ceramic susceptors of this sort. The ceramic susceptors disclosed in Pat. App. Pub. No. 2002-237375 are structures in the surface or interior of which a resistive heating element is formed, and in the edge portion of which pins for fitting to a semiconductor wafer are formed, and in which to the inside of the pins numerous bumps that come into contact with the semiconductor wafer are formed.

[0006] The case with this invention is that the numerous bumps that come into contact with a semiconductor wafer on the heating face of the ceramic substrate enable the temperature to be raised rapidly and the heating face to be given a uniform temperature. The invention has it that constituting the tops of the foregoing bumps in flat surfaces is desirable. Nevertheless, a problem with these multitudes of bumps has been that if the flat portion of the bumps singly is too large, the isothermal properties of a wafer

carried on the susceptor can be disrupted; and in some cases the wafer cannot be de-chucked from the carrying surface.

[0007] Scaling-up of semiconductor substrates has been moving forward in recent years, however. For example, with silicon (Si) wafers, a transition from 8-inch to 12-inch is in progress. Consequent on this diametric enlargement of the semiconductor substrate, that the temperature distribution in the heating surface (retaining surface) of semiconductor substrates on ceramic susceptors be within  $\pm 1.0\%$  has become a necessity; that it be within  $\pm 0.5\%$  has, moreover, become an expectation.

#### **SUMMARY OF INVENTION**

[0008] The present invention has been brought about to address the foregoing issues. In particular, an object of the present invention is to realize a wafer holder for semiconductor manufacturing device, and semiconductor manufacturing device in which the holder is installed, which enhances the isothermal properties of the wafers carried and with which wafer removability is excellent.

[0009] The present invention was arrived at by discovering that with the semiconductor-manufacturing-device wafer holder set forth in the foregoing Japanese Pat. App. Pub.

No. 2002-237375, if the surface area of the flat portion of a single nub turns out to be too large, a wafer set in place on the holder will prove difficult to de-chuck, and moreover, the isothermal properties of the wafer will be disrupted.

[0010] Namely, in a wafer holder having a wafer-carrying surface according to the present invention, a number of nubs having a flat portion are formed on the wafer-carrying surface, and the surface area of the flats on the nubs is  $70 \text{ mm}^2$  or less per nub. In addition, the total surface area of the flats on the multiple nubs is 40% or less of the surface area of the wafers that the holder carries; preferably the surface area of the flat on a nub is  $30 \text{ mm}^2$  or less, while the total surface area is preferably 10% or less. What is more, semiconductor manufacturing device in which a wafer holder such as just described is installed, temperature of wafers that are the processed objects proves to be more uniform than is conventional, which enables manufacturing semiconductors with better throughput.

[0011] From the following detailed description in conjunction with the accompanying drawings, the foregoing and other objects, features, aspects and advantages of the present invention will become readily apparent to those skilled in

the art.

## **BRIEF DESCRIPTION OF DRAWINGS**

- [0012] Fig. 1 in a plan view schematically illustrates one example of a wafer holder according to the present invention;
- [0013] Fig. 2 is a schematic view of planar section A–A in Fig. 1;
- [0014] Fig. 3 is a schematic view representing temperature distribution in the present invention through a wafer section; and
- [0015] Fig. 4 is a schematic view representing temperature distribution in comparative example through a wafer section.

## **DETAILED DESCRIPTION**

- [0016] The inventors discovered that in order to get the temperature distribution of a wafer that a wafer holder 1 (Fig. 1) carries to be within  $\pm 1.0\%$ , multiple nubs 2 having a flat portion should be formed on its wafer-carrying surface 4, and the surface area of the flats on the nubs should be  $70 \text{ mm}^2$  or less per nub.
- [0017] The wafer holder heats a wafer by means of a resistive heating element 5 formed either in the interior of the wafer holder, or else on a surface other than its wafer-carrying surface, wherein a predetermined process(es) is carried out on the wafer. At that time, the heat of the

wafer holder being heated is transferred to the wafer via the nubs. If the surface area of the flat on the nubs singly exceeds  $70 \text{ mm}^2$ , however, when the heat generated by the resistive heating element is transferred via the nubs, more of a distribution in temperature in the wafer obverse surface would be liable to arise. Uneven drop in the temperature of a carried wafer means that for example wherein a film deposition process is carried out on the wafer, the thickness and properties of the formed film will fluctuate.

[0018] For these reasons, the slighter the distribution in obverse-surface temperature of a carried wafer the better; and in terms of temperature distribution in practice, isothermal ratings of within  $\pm 1.0\%$ , and more desirably, isothermal ratings of within  $\pm 0.5\%$ , are being sought. It was discovered that in order to gain an isothermal rating along these lines, the per-nub surface area of the flats should be made  $70 \text{ mm}^2$  or less.

[0019] The wafer holder is heated by passing current through the resistive heating element. The heat therein generated by the resistive heating element spreads into the wafer holder and is transmitted to the wafer via the nubs. In terms of the temperature distribution in a cross section of

the wafer directly over the nubs, the temperature in the lower portion of the wafer directly above the nubs becomes maximal, while the temperature will diminish in the upper portion and radial direction of the wafer. It was discovered that if the surface area of the flat on the nubs is  $70 \text{ mm}^2$  or less, directly above a nub as illustrated schematically in Fig. 3 a high-temperature zone 7 will be present, and encompassing that region, a low-temperature zone 8 where the temperature is lower than the high-temperature zone will be present, and that inasmuch as the high-temperature zone 7 and low-temperature zone 8 do not reach to the wafer obverse surface, the wafer obverse-surface temperature proves to be approximately uniform.

[0020] It was meanwhile discovered that if the surface area of the flat on the nubs exceeds  $70 \text{ mm}^2$ , however, the high-temperature zone 7 will reach the wafer obverse surface, as shown schematically in Fig. 4, and the low-temperature zone 8 where the temperature is lower than that will appear at the wafer obverse surface, which will produce a distribution in the wafer obverse-surface temperature.

[0021] Consequently, wafer obverse-surface temperature distribution can be brought within  $\pm 1.0\%$  if the surface area of

the flat on the nubs is  $70 \text{ mm}^2$  or less. Likewise, a surface area of the flats on the nubs of  $30 \text{ mm}^2$  or less is more preferable, since the wafer obverse-surface temperature distribution can then be within  $\pm 0.5\%$ .

[0022] It is also preferable that the total surface area of the flats on the nubs is 40% or less of the wafer surface area. In wafer holders whose wafer-retaining face is not fashioned with nubs, since a wafer comes entirely into contact with the wafer-retaining face the wafer is brought into a state in which it is cohered to and is hard to de-chuck from the wafer-retaining face. The total surface area of the flats on the nubs exceeding 40% of the wafer surface area will, like the situation in which wafer-retaining face is not fashioned with nubs, make the wafer hard to de-chuck, inviting wafer breakage and also placing strain on the wafers.

[0023] Making the total surface area of the flats on the nubs 40% or less of the wafer surface area is accordingly preferable inasmuch as it means that the wafers will be readily de-chucked and that incidence of the problems just described will be slight. What is more, making the total surface area of the flats 10% or less is more preferable in that problems when the wafers are de-chucked disappear completely.



[0024] Insofar as the substances for a wafer holder according to the present invention are insulative ceramics, they are not particularly restricted, but aluminum nitride (AlN) is preferable for its high thermal conductivity and superior corrosion resistance. In the following, a method according to the present invention of manufacturing a wafer holder in a AlN instance will be described in detail.

[0025] An AlN raw-material powder whose specific surface area is 2.0 to 5.0 m<sup>2</sup>/g is preferable. The sinterability of the aluminum nitride declines if the specific surface area is less than 2.0 m<sup>2</sup>/g. Handling proves to be a problem if on the other hand the specific surface area is over 5.0 m<sup>2</sup>/g, because the powder coherence becomes extremely strong. Furthermore, the quantity of oxygen contained in the raw-material powder is preferably 2 wt. % or less. In sintered form, its thermal conductivity deteriorates if the oxygen quantity is in excess of 2 wt. %. It is also preferable that the amount of metal impurities contained in the raw-material powder other than aluminum be 2000 ppm or less. The thermal conductivity of the powder in sintered form deteriorates if the amount of metal impurities exceeds this range. In particular, the content respectively of Group IV elements such as Si, and elements of the iron

family, such as Fe, which have a serious worsening effect on the thermal conductivity of the sinter, is advisably 500 ppm or less.

[0026] Because AlN is not a readily sinterable material, adding a sintering promoter to the AlN raw-material powder is advisable. The sintering promoter added preferably is a rare-earth element compound. Since rare-earth element compounds react with aluminum oxides or aluminum oxynitrides present on the surface of the particles of the aluminum nitride powder, acting to promote densification of the aluminum nitride and to eliminate oxygen being a causative factor that worsens the thermal conductivity of an aluminum nitride sinter, they enable the thermal conductivity of aluminum sinters to be improved.

[0027] Yttrium compounds, whose oxygen-eliminating action is particularly pronounced, are preferable rare-earth element compounds. The amount added is preferably 0.01 to 5 wt. %. If less than 0.01 wt. %, producing ultrafine sinters is problematic, along with which the thermal conductivity of the sinters deteriorates. Added amounts in excess of 5 wt. % on the other hand lead to sintering promoter being present at the grain boundaries in an aluminum nitride sinter, and consequently, if the aluminum nitride sinter is

employed under a corrosive atmosphere, the sintering promoter present along the grain boundaries gets etched, becoming a source of loosened grains and particles. More preferably the amount of sintering promoter added is 1 wt. % or less. If less than 1 wt. % sintering promoter will no longer be present even at the grain boundary triple points, which improves the corrosion resistance.

[0028] To characterize the rare-earth compounds further: oxides, nitrides, fluorides, and stearic oxide compounds may be employed. Among these oxides, being inexpensive and readily obtainable, are preferable. By the same token, stearic oxide compounds are especially suitable since they have a high affinity for organic solvents, and if the aluminum nitride raw-material powder, sintering promoter, etc. are to be mixed together in an organic solvent, the fact that the sintering promoter is a stearic oxide compound will heighten the miscibility.

[0029] Next, the aluminum nitride raw-material powder, sintering promoter as a powder, a predetermined volume of solvent, a binder, and further, a dispersing agent or a coalescing agent added as needed, are mixed together. Possible mixing techniques include ball-mill mixing and mixing by ultrasound. Mixing can thus produce a raw material

slurry.

[0030] The obtained slurry can be molded, and by sintering the molded product, an aluminum nitride sinter can be produced. Co-firing and post-metallization are two possible methods as a way of doing this.

[0031] Post-metallization will be described first. Granules are prepared from the slurry by means of a technique such as spray-drying. The granules are inserted into a predetermined mold and subject to press-molding. The pressing pressure therein desirably is  $0.1 \text{ t/cm}^2$  or more. With pressure less than  $0.1 \text{ t/cm}^2$ , in most cases sufficient strength in the molded mass cannot be produced, making it liable to break in handling.

[0032] Although the density of the molded mass will differ depending on the amount of binder contained and on the amount of sintering promoter added, preferably it is  $1.5 \text{ g/cm}^3$  or more. Densities less than  $1.5 \text{ g/cm}^3$  would mean a relatively large distance between particles in the raw-material powder, which would hinder the progress of the sintering. At the same time, the molded mass density preferably is  $2.5 \text{ g/cm}^3$  or less. Densities of more than  $2.5 \text{ g/cm}^3$  would make it difficult to eliminate sufficiently the binder from within the molded mass in a degreasing pro-

cess of a subsequent step. It would consequently prove difficult to produce an ultrafine sinter as described earlier.

[0033] Next, heating and degreasing processes are carried out on the molded mass within a non-oxidizing atmosphere.

Carrying out the degreasing process under an oxidizing atmosphere such as air would degrade the thermal conductivity of the sinter, because the AlN powder would become superficially oxidized. Preferable non-oxidizing ambient gases are nitrogen and argon. The heating temperature in the degreasing process is preferably 500°C or more and 1000°C or less. With temperatures of less than 500°C, surplus carbon is left remaining within the laminate following the degreasing process because the binder cannot sufficiently be eliminated, which interferes with sintering in the subsequent sintering step. On the other hand, at temperatures of more than 1000°C, the ability to eliminate oxygen from the oxidized coating superficially present on the surface of the AlN powder deteriorates, such that the amount of carbon left remaining is too little, degrading the thermal conductivity of the sinter.

[0034] The amount of carbon left remaining within the molded mass after the degreasing process is preferably 1.0 wt. % or less. If carbon in excess of 1.0 wt. % remains, it will in-

terfere with the sintering, which would mean that ultrafine sinters could not be produced.

[0035] Next, sintering is carried out. The sintering is carried out within a non-oxidizing nitrogen, argon, or like atmosphere, at a temperature of 1700 to 2000 °C. Therein the moisture contained in the ambient gas such as nitrogen that is employed is preferably  $-30^{\circ}\text{C}$  or less given in dew point. If it were to contain more moisture than this, the thermal conductivity of the sinter would likely be degraded, because the AlN would react with the moisture within the ambient gas during sintering and form nitrides. Another preferable condition is that the volume of oxygen within the ambient gas be 0.001 vol. % or less. A larger volume of oxygen would lead to a likelihood that the AlN would oxidize, impairing the sinter thermal conductivity.

[0036] As another condition during sintering, the jig employed is suitably a boron nitride (BN) molded part. Inasmuch as the jig as a BN molded part will be sufficiently heat resistant against the sintering temperatures, and superficially will have solid lubricity, when the laminate contracts during sintering, friction between the jig and the laminate will be lessened, which will enable sinters to be produced with little distortion.

[0037] The obtained sinter is subjected to processing according to requirements. In cases where a conductive paste is to be screen-printed onto the sinter in a succeeding step, the surface roughness is preferably 5  $\mu\text{m}$  or less in Ra. If over 5  $\mu\text{m}$ , in screen printing to form circuits, defects such as blotting or pinholes in the pattern are liable to arise. More suitable is a surface roughness of 1  $\mu\text{m}$  or less in Ra.

[0038] In polishing to the abovementioned surface roughness, although cases in which both sides of the sinter are screen printed are a matter of course, even in cases where screen printing is effected on one side only the polishing process is best carried out on the face on the side opposite the screen-printing face. This is because polishing only the screen-printing face would mean that during screen printing, the sinter would be supported on the unpolished face, and in that situation burrs and debris would be present on the unpolished face, destabilizing the fixedness of the sinter such that the circuit pattern by the screen printing might not be drawn well.

[0039] Furthermore, at this point the thickness uniformity (parallelism) between the processed faces is preferably 0.5 mm or less. Thickness uniformity exceeding 0.5 mm can

lead to large fluctuations in the thickness of the conductive paste during screen printing. Particularly suitable is a thickness uniformity of 0.1 mm or less. Another preferable condition is that the planarity of the screen-printing face be 0.5 mm or less. If the planarity exceeds 0.5 mm, in that case too there can be large fluctuations in the thickness of the conductive paste during screen printing. Particularly suitable is a planarity of 0.1 mm or less.

[0040] Screen printing is used to spread a conductive paste and form the electrical circuits onto a sinter having undergone the polishing process. The conductive paste can be obtained by mixing together with a metal powder an oxidized powder, a binder, and a solvent according to requirements. The metal powder is preferably tungsten, molybdenum or tantalum, since their thermal expansion coefficients match those of ceramics.

[0041] Adding the oxidized powder to the conductive paste is also to enhance the strength with which it bonds to AlN. The oxidized powder preferably is an oxide of Group IIa or Group IIIa elements, or is  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ , or a like oxide. Yttrium oxide is especially preferable because it has very good wettability with AlN. The amount of such oxides added is preferably 0.1 to 30 wt. %. If the amount is less



than 0.1 wt. %, the bonding strength between AlN and the metal layer being the circuit that has been formed deteriorates. On the other hand, amounts in excess of 30 wt. % make the electrical resistance of the circuit metal layer high.

[0042] The thickness of the conductive paste is preferably 5  $\mu\text{m}$  or more and 100  $\mu\text{m}$  or less in terms of its post-drying thickness. If the thickness were less than 5  $\mu\text{m}$  the electrical resistance would be too high and the bonding strength decline. Likewise, if in excess of 100  $\mu\text{m}$  the bonding strength would deteriorate in that case too.

[0043] Also preferable is that in the patterns for the circuits that are formed, in the case of the heater circuit (resistive heating element circuit), the pattern spacing be 0.1 mm or more. With a spacing of less than 0.1 mm, shorting will occur when current flows in the resistive heating element and, depending on the applied voltage and the temperature, leakage current is generated. Particularly in cases where the circuit is employed at temperatures of 500°C or more, the pattern spacing preferably should be 1 mm or more; more preferable still is that it be 3 mm or more.

[0044] After the conductive paste is degreased, baking follows. Degreasing is carried out within a non-oxidizing nitrogen,

argon, or like atmosphere. The degreasing temperature is preferably 500°C or more. At less than 500°C, elimination of the binder from the conductive paste is inadequate, leaving behind carbon in the metal layer that during baking will form carbides with the metal and consequently raise the electrical resistance of the metal layer.

[0045] The baking is suitably done within a non-oxidizing nitrogen, argon, or like atmosphere at a temperature of 1500°C or more. At temperatures of less than 1500°C, the post-baking electrical resistance of the metal layer turns out too high because the baking of the metal powder within the paste does not proceed to the grain growth stage. A further baking parameter is that the baking temperature should not surpass the firing temperature of the ceramic produced. If the conductive paste is baked at a temperature beyond the firing temperature of the ceramic, dispersive volatilization of the sintering promoter incorporated within the ceramic sets in, and moreover, grain growth in the metal powder within the conductive paste is accelerated, impairing the bonding strength between the ceramic and the metal layer.

[0046] In order to ensure that the metal layer is electrically isolated, an insulative coating can be formed on the metal

layer. Preferably the insulative coating substance is the same substance as the ceramic on which the metal layer is formed. Problems such as post-sintering warpage arising from the difference in thermal expansion coefficient will occur if the ceramic and insulative coating substances differ significantly. For example, in a case where the ceramic is AlN, a predetermined amount of an oxide/carbide of a Group IIa element or a Group IIIa element can be added to and mixed together with AlN powder, a binder and a solvent added and the mixture rendered into a paste, and the paste can be screen-printed to spread it onto the metal layer.

[0047] In that case, the amount of sintering promoter added preferably is 0.01 wt. % or more. With an amount less than 0.01 wt. % the insulative coating does not densify, making it difficult to secure electrical isolation of the metal layer. It is further preferable that the amount of sintering promoter not exceed 20 wt. %. Surpassing 30 wt. % leads to excess sintering promoter invading the metal layer, which can end up altering the metal-layer electrical resistance. Although not particularly limited, the spreading thickness preferably is 5  $\mu$ m or more. This is because securing electrical isolation proves to be problematic at

less than 5  $\mu\text{m}$ .

[0048] Further according to the present method, the ceramic as substrates can be laminated according to requirements. Lamination may be done via an adhesive agent. The adhesive agent--being a compound of Group IIa or Group IIIa elements, and abinder and solvent, added to an aluminum oxide powder or aluminum nitride powder and made into a paste--is spread onto the bonding surface by a technique such as screen printing. The thickness of the applied adhesive agent is not particularly restricted, but preferably is 5  $\mu\text{m}$  or more. Bonding defects such as pinholes and bonding irregularities are liable to arise in the adhesive layer with thicknesses of less than 5  $\mu\text{m}$ .

[0049] The ceramic substrates onto which the adhesive agent has been spread are degreased within a non-oxidizing atmosphere at a temperature of 500°C or more. The ceramic substrates are thereafter bonded to one another by stacking the ceramic substrates together, applying a predetermined load to the stack, and heating it within a non-oxidizing atmosphere. The load preferably is 0.05 kg/cm<sup>2</sup> or more. With loads of less than 0.05 kg/cm<sup>2</sup> sufficient adhesive strength will not be obtained, and otherwise defects in the joint will likely occur.

[0050] Although the heating temperature for bonding is not particularly restricted as long as it is a temperature at which the ceramic substrates adequately bond to one another via the adhesive layers, preferably it is 1500°C or more. At less than 1500°C adequate adhesive strength proves difficult to gain, such that defects in the bond are liable to arise. Nitrogen or argon is preferably employed for the non-oxidizing atmosphere during the degreasing and bonding just discussed.

[0051] A ceramic laminated sinter that serves as a wafer holder thus can be produced as in the foregoing. As far as the electrical circuits are concerned, it should be understood that if they are heater circuits for example, then a molybdenum coil can be utilized, and in the electrostatic-chuck electrode and RF electrode cases, molybdenum or tungsten mesh can be, without employing conductive paste.

[0052] In this case, the molybdenum coil or the mesh can be built into the AlN raw-material powder, and the wafer holder can be fabricated by hot pressing. While the temperature and atmosphere in the hot press may be on par with the AlN sintering temperature and atmosphere, the hot press desirably applies a pressure of 10 kg/cm<sup>2</sup> or more. With pressure of less than 10 kg/cm<sup>2</sup>, the wafer holder might

not exhibit its capabilities, because gaps arise between the AlN and the molybdenum coil or the mesh.

[0053] Co-firing will now be described. The earlier-described raw-material slurry is molded into a sheet by doctor blading. The sheet-molding parameters are not particularly limited, but the post-drying thickness of the sheet advisably is 3 mm or less. The sheet thickness surpassing 3 mm leads to large shrinkage in the drying slurry, raising the probability that fissures will be generated in the sheet.

[0054] A metal layer of predetermined form that serves as an electrical circuit is formed onto the abovementioned sheet using a technique such as screen printing to spread onto it a conductive paste. The conductive paste utilized can be the same as that which was described under the post-metallization method. Nevertheless, not adding an oxidized powder to the conductive paste does not hinder the co-firing method.

[0055] Subsequently, sheets that have undergone circuit formation are laminated with sheets that have not. Lamination is by setting the sheets each into position to stack them together. Therein, according to requirements, a solvent is spread on between sheets. In the stacked state, the sheets are heated as may be necessary. In cases where the stack

is heated, the heating temperature is preferably 150°C or less. Heating to temperatures in excess of this greatly deforms the laminated sheets. Pressure is then applied to the stacked-together sheets to unitize them. The applied pressure is preferably within a range of from 1 to 100 MPa. At pressures less than 1 MPa, the sheets are not adequately unitized and can peel apart during subsequent processes. Likewise, if pressure in excess of 100 MPa is applied, the extent to which the sheets deform becomes too great.

[0056] This laminate undergoes a degreasing process as well as sintering, in the same way as with the post-metallization method described earlier. Parameters such as the temperature in degreasing and sintering, and the amount of carbon are the same as with post-metallization. In the previously described screen printing of a conductive paste onto sheets, a wafer holder having a plurality of electrical circuits can be readily fabricated by printing heater circuits, electrostatic-chuck electrodes, etc. respectively onto a plurality of sheets and laminating them. In this way a ceramic laminated sinter that serves as a wafer holder can be produced.

[0057] The obtained ceramic laminated sinter is subject to pro-

cessing according to requirements. Routinely with semiconductor manufacturing device, in the sintered state the ceramic laminated sinter often cannot be gotten into the precision demanded. The planarity of the wafer-carrying surface as an example of processing precision is preferably 0.5 mm or less; moreover 0.1 mm or less is particularly preferable. The planarity surpassing 0.5 mm is apt to give rise to gaps between the wafer and the wafer holder, keeping the heat of the wafer holder from being uniformly transmitted to the wafer and making likely the generation of temperature irregularities in the wafer.

[0058] A further preferable condition is that the surface roughness of the wafer-carrying surface be 5  $\mu\text{m}$  in Ra. If the roughness is over 5  $\mu\text{m}$  in Ra, grains loosened from the AlN due to friction between the wafer holder and the wafer can grow numerous. Particles loosened in that case become contaminants that have a negative effect on processes, such as film deposition and etching, on the wafer. Furthermore, then, a surface roughness of 1  $\mu\text{m}$  or less in Ra is ideal.

[0059] In addition, the nubs having a flat portion according to the present invention can be fashioned utilizing a publicly known processing technique such as machining or sand



blasting. Under the circumstances, inasmuch as the flat portion of the nubs is the wafer-retaining face mentioned earlier, when fashioning the nubs, care must be taken that the surface roughness of the flats and their planarity as a whole be within the just-noted surface-roughness and planarity ranges for the wafer-carrying surface.

[0060] A wafer holder base part can thus be fabricated as in the foregoing. Furthermore, a shaft is attached to the wafer holder. Although the shaft substance is not particularly limited as long as its thermal expansion coefficient is not appreciably different from that of the wafer-holder ceramic, the difference in thermal expansion coefficient between the shaft substance and the wafer holder preferably is  $5 \times 10^{-6}$  K or less.

[0061] If the difference in thermal expansion coefficient exceeds  $5 \times 10^{-6}$  K, cracks can arise adjacent the joint between the wafer holder and the shaft when it is being attached; but even if cracks do not arise when the two are joined, splitting and cracking can occur in the joint in that it is put through heating cycling in the course of being repeatedly used. For cases in which the wafer holder is AlN, for example, the shaft substance is optimally AlN; but silicon nitride, silicon carbide, or mullite can be used.

[0062] The shaft is mounted by joining it to the wafer holder via an adhesive layer. The adhesive layer constituents preferably are composed of AlN and  $\text{Al}_2\text{O}_3$ , as well as rare-earth oxides. These constituents are preferable because of their favorable wettability with ceramics such as the AlN that is the substance of the wafer holder and the shaft, which makes the joint strength relatively high, and readily produces a gastight joint surface.

[0063] Likewise, a ZnO-system glass ceramic can also be utilized as an adhesive layer constituent. This option is preferable in that the shaft can be joined at a relatively low temperature since the crystallization temperature of glass is 700 to 800°C. Nevertheless, since ambient gases within the process chamber in the semiconductor manufacturing device will in some cases invade the glass constituent, depending on the semiconductor manufacturing conditions there will be situations in which glass ceramics cannot be employed.

[0064] The planarity of the respective joining faces of the shaft and wafer holder to be joined preferably is 0.5 mm or less. Planarity greater than this makes gaps liable to occur in the joining faces, impeding the production of a joint having adequate gastightness. A planarity of 0.1 mm or

less is more suitable. Here, still more suitable is a planarity of the wafer holder joining faces of 0.02 mm or less. Likewise, the surface of the respective joining faces preferably is 5  $\mu\text{m}$  or less in Ra. Surface roughness exceeding this would then also mean that gaps are liable to occur in the joining faces. A surface roughness of 1  $\mu\text{m}$  or less in Ra is still more suitable.

[0065] Subsequently, electrodes are attached to the wafer holder. The attaching can be done according to publicly known techniques. For example, the side of the wafer holder opposite its wafer-retaining face, may be spot faced through to the electrical circuits, and metallization carried out on the circuit, or without metallizing, electrodes of molybdenum, tungsten, etc. may be connected to it directly using an active metal brazing material. The electrodes can thereafter be plated as needed to improve their resistance to oxidation. In this way, a wafer holder for semiconductor manufacturing device can be fabricated.

[0066] Moreover, semiconductor wafers can be processed on a wafer holder according to the present invention, assembled into a semiconductor manufacturing device. Inasmuch as the temperature of the wafer-retaining face of a wafer holder by the present invention is uniform, the tem-

perature distribution in the wafer will be more uniform than is conventional, to yield stabilized characteristics in terms of deposited films, heating process, etc.

[0067] Embodiments

[0068] *Embodiment 1*

[0069] 99 parts by weight aluminum nitride powder and 1 part by weight  $Y_2O_3$  powder were mixed and blended with 10 parts by weight polyvinyl butyral as a binder and 5 parts by weight dibutyl phthalate as a solvent, and doctor-bladed into a green sheet 430 mm in diameter and 1.0 mm in thickness. Here, an aluminum nitride powder having a mean particle diameter of 0.6  $\mu m$  and a specific surface area of 3.4  $m^2/g$  was utilized. In addition, a tungsten paste was prepared utilizing 100 parts by weight of a tungsten powder whose mean particle diameter was 2.0  $\mu m$ ; and per that, 1 part by weight  $Y_2O_3$  and 5 parts by weight ethyl cellulose, being a binder; and butyl Carbitol™ as a solvent. A pot mill and a triple-roller mill were used for mixing. This tungsten paste was formed into a heater circuit pattern by screen-printing onto the green sheet.

[0070] Pluralities of separate green sheets of thickness 1.0 mm were laminated onto the green sheet printed with the

heater circuit to create laminates. Lamination was carried out by stacking the sheets in place in a mold, and thermopressing 2 minutes in a press at a pressure of 10 MPa while maintaining 50°C heat. The laminates were thereafter degreased within a nitrogen atmosphere at 600°C, and sintered within a nitrogen atmosphere under time and temperature conditions of 3 hours and 1800°C, whereby wafer holders were produced. Here, after sintering a polishing process was performed on the wafer-retaining face so that it would be 1  $\mu$ m or less in Ra, and on the shaft-joining face so that it would be 5  $\mu$ m or less in Ra. The wafer holders were also processed to true their outer diameter. The dimensions of the post-processing wafer holders were 340 mm outside diameter and 20 mm thickness. Also, the distance separating the wafer-carrying surface from the RF-generating electrode circuit was 1 mm.

[0071] Next, wafer holders on whose wafer-carrying surface nubs as follows were fashioned by a drilling process were fabricated. Namely: wafer holders fashioned with 532 nubs (arranged in a 15 mm pitch), with the diameter of the flats on the nubs being 1, 2.54, 4, 6, 8 and 10 mm; and wafer holders fashioned with 127 nubs (arranged in a 45 mm

pitch), with the diameter of the flats on the nubs being 1, 2.54, 4, 6, 8, 10, 12, 15 and 20 mm.

[0072] The heater circuits in the wafer holders were partially exposed by spot-facing through the surface in two locations on the side opposite the wafer-retaining face, up to the heater circuit. Electrodes made of tungsten were connected directly to the exposed portions of the heater circuits utilizing an active metal brazing material. The wafer holders were heated by passing current through the electrodes, and their isothermal ratings were measured. Measurement of isothermal ratings was by setting a 12-inch wafer temperature gauge on the wafer-retaining faces and measuring their temperature distributions. It should be understood that the power supply was adjusted so that the temperature in the midportion of the wafer temperature gauge would be 550°C. The isothermal rating results are set forth in Table I and Table II.

[0073] In addition, tabulated and entered under "Lift test" in Tables I and II are: as "Good," wafer holders with which breakage and like problems in the wafers did not arise at all when the wafers were lifted off the wafer holders by means of a not-illustrated wafer lift pin; as "Fair," wafer holders with which breakage arose in part of the wafer;

and as "NG" (no good), the wafer holder with which the wafer was broken. It should be understood that in Tables I and II "Surface area" is the surface area of the flat on the nubs singly, while "Relative surface area" is the ratio of the total surface area of the flats on the nubs to the surface area of the (12-inpch diameter) wafers.

[0074] Table I.

[0075]

| No. | Nub dia.<br>(mm) | Surface<br>area (mm <sup>2</sup> ) | Nub count | Relative sur-<br>face area<br>(%) | Lift test | Isothermal<br>rating (%) |
|-----|------------------|------------------------------------|-----------|-----------------------------------|-----------|--------------------------|
| 1   | 1                | 0.8                                | 532       | 0.6                               | Good      | ±0.3                     |
| 2   | 2.54             | 5.1                                | 532       | 3.7                               | Good      | ±0.3                     |
| 3   | 4                | 12.6                               | 532       | 9.2                               | Good      | ±0.4                     |
| 4   | 6                | 28.3                               | 532       | 20.6                              | Fair      | ±0.5                     |
| 5   | 8                | 50.3                               | 532       | 36.6                              | Fair      | ±0.8                     |
| 6   | 10               | 78.5                               | 532       | 57.4                              | NG        | ±1.2                     |

[0076] Table II.

[0077]

| No. | Nub dia.<br>(mm) | Surface<br>area (mm <sup>2</sup> ) | Nub count | Relative sur-<br>face area<br>(%) | Lift test | Isothermal<br>rating (%) |
|-----|------------------|------------------------------------|-----------|-----------------------------------|-----------|--------------------------|
| 7   | 1                | 0.8                                | 127       | 0.1                               | Good      | ±0.3                     |
| 8   | 2.54             | 5.1                                | 127       | 0.9                               | Good      | ±0.3                     |
| 9   | 4                | 12.6                               | 127       | 2.2                               | Good      | ±0.4                     |
| 10  | 6                | 28.3                               | 127       | 4.9                               | Good      | ±0.5                     |
| 11  | 8                | 50.3                               | 127       | 8.7                               | Good      | ±0.9                     |

|    |    |       |     |      |      |      |
|----|----|-------|-----|------|------|------|
| 12 | 10 | 78.5  | 127 | 13.7 | Fair | ±1.1 |
| 13 | 12 | 113.1 | 127 | 19.7 | Fair | ±1.2 |
| 14 | 15 | 176.7 | 127 | 30.8 | Fair | ±1.5 |
| 15 | 20 | 314.2 | 127 | 54.7 | NG   | ±1.6 |

[0078] As is evident from Tables I and II, by making the surface area of the flat on the nubs singly  $70 \text{ mm}^2$  or less, the temperature distribution in the wafer obverse surface can be brought to within  $\pm 1\%$ . What is more, by making the aforesaid surface area  $30 \text{ mm}^2$  or less, the temperature distribution in the wafer obverse surface can be brought to within  $\pm 0.5\%$ . Meanwhile, making the total surface area of the flats on the nubs 40% or less of the wafer surface area can make it so that problems when de-chucking the wafers hardly occur; making it 10% or less can make it so that problems when de-chucking the wafers do not occur at all.

[0079] *Embodiment 2*

[0080] The wafer holders of Tables I and II were assembled into semiconductor manufacturing device, wherein TiN films were formed onto silicon wafers 12 inches in diameter. The results were that in the cases in which wafer holders Nos. 6 and 15 were used, fluctuations in the TiN film thickness were a large 15% or more, and the wafers were



damaged when the wafers were de-chucked; in the cases in which wafer holders Nos. 12–14 were utilized, fluctuations in the TiN film thickness were a large 15% or more, and when the wafers were de-chucked there was some slight breakage in the wafers; but in the cases in which wafer holders Nos. 1–5 and 7–11 were utilized, fluctuations in the TiN film thickness were a small 10% or less, excellent TiN films could be formed, and there were no problems at all when de-chucking the wafers.

[0081] According to the present invention as given in the foregoing, with nubs having a flat portion, making the surface area of the flat on the nubs singly  $70\text{ mm}^2$  or less enables the realization of wafer holders and semiconductor manufacturing device whose isothermal rating is outstanding. Likewise, making the total surface area of the flats on the nubs 40% or less of the wafer surface area enables the incidence of problems when de-chucking the wafers to be kept under control.

[0082] Only selected embodiments have been chosen to illustrate the present invention. To those skilled in the art, however, it will be apparent from the foregoing disclosure that various changes and modifications can be made herein without departing from the scope of the invention as defined

in the appended claims. Furthermore, the foregoing description of the embodiments according to the present invention is provided for illustration only, and not for limiting the invention as defined by the appended claims and their equivalents.